Calculation of Most Efficient Volume of Detection by Using the Differential Volume Method in the EXVol Code

M.Y. Kang[a*], Euntaek Yoon[a], G.M. Sun[b] and H.D. Choi[a]
[a]*Department of Nuclear Engineering, Seoul National University, Seoul, Korea*
[b]*Korea Atomic Energy Research Institute (KAERI), Daejeon, Korea*
[*]*Corresponding author: kangmy@snu.ac.kr*

1. Introduction

To calculate the full energy (FE) absorption peak efficiency for arbitrary volume sample, we developed and verified the EXVol (Efficiency calculator for eXtended Voluminous source) code which is based on effective solid angle method [1]. The procedure for semi-empirical determination of the FE efficiency for the arbitrary volume sources and the calculation principles and processes about EXVol code is referred to, and the code was validated with HPGe detectors in previous study [2].

Correction techniques for factors that interfere with γ-ray spectrum analysis are required for reliable nuclear characterization and radioactivity determination. And in the measurement of voluminous source of various forms and media, it is necessary to calibrate the effects of the self-attenuation and coincidence summing of the γ-ray depending on the volume and density of the sample.

In this study, the performance of the EXVol code was extended to obtain the detection efficiency distribution at a specific position in the volume sample. And we obtained γ-ray detection efficiency and determined the most efficient volume contributing to detection efficiency of the large voluminous Si ingot source.

2. Methods and Results

We have established a method for calculating the detection efficiency of the differential volume corresponding to a specific position in the source. It is possible to describe the source area as a non-uniform two-dimensional (r,z) source. And decompose and set it into several sets of volume units. Users can equally divid (r,z) coordinate system to calculate the detection efficiency at a specific position of a cylindrical volume source. By determining the detection efficiency for differential volume units, the total radiative absolute distribution and the correction factor of the detection efficiency can be obtained from the nondestructive measurement of the source.

2.1 Detection efficiency at a specific position

We have extended the performance of the EXVol code so that the detection efficiency can be calculated at a specific position by equally dividing the source into the (r, z) direction to the size desired by the user. The calculation result is contour plotted so that the distribution of detection efficiency can be visually confirmed.

In order to check the performance of the EXVol code, Si ingot of 4 inches in diameter and 20 cm in height were used as source. And it was equally divided into 10 pieces in the r-direction and the z-direction respectively. The results are shown in Figure 1.

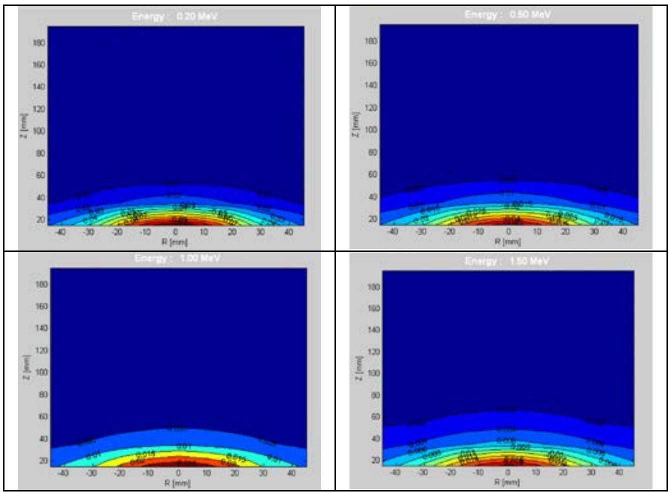

Fig. 1. Distribution of detection efficiency of Si ingot by energy. Two of the upper lines are the results at 200 keV and 500 kev, and two of the lower lines are the results at 1000 keV and 1500 keV.

2.2 The Most Efficient Volume of Detection

As a result of various simulations while increasing the size of the source, it was confirmed that the source height which contributes to the actual efficiency is limited as the height of ingot becomes longer. As the position of the differential volume in the source moves away from the detector, the solid angle decreases and the self-attenuation effect occurs. And as the count rate saturation occurs, the total detection efficiency converges to a constant value. This result shows the necessity of determination of effective height and efficient volume. The Most Efficient Volume of Detection (V_{MED}) is determined by the following method.

- In order to obtain V_{MED}, the detection efficiency of the calculation results is sorted in descending order.
- Among them, the volume that contributes to the actual detection efficiency is determined by the sum of

the differential volumes (ΔV) in order from the highest efficiency. It is shown in equation (1).

$$V_{MED} = \sum_{i \in V_{MED}} (\Delta V)_i \quad (1)$$

Si ingot with a height of 20 cm was equally divided into 10 pieces in the r-direction and z-direction, respectively, and the distribution of detection efficiency and V_{MED} were obtained. The result is shown in Figure 2. Figure 2 shows the GUI screen of the EXVol code that shows the calculation results. The x-axis of the graph at the top place of the figure is the number of differential volume and the y-axis is the summed detection efficiency. By looking at the movement of the red dotted line, it can be seen that as the energy increases, the number of differential volumes contributing to the efficiency increases and thus V_{MED} increases.

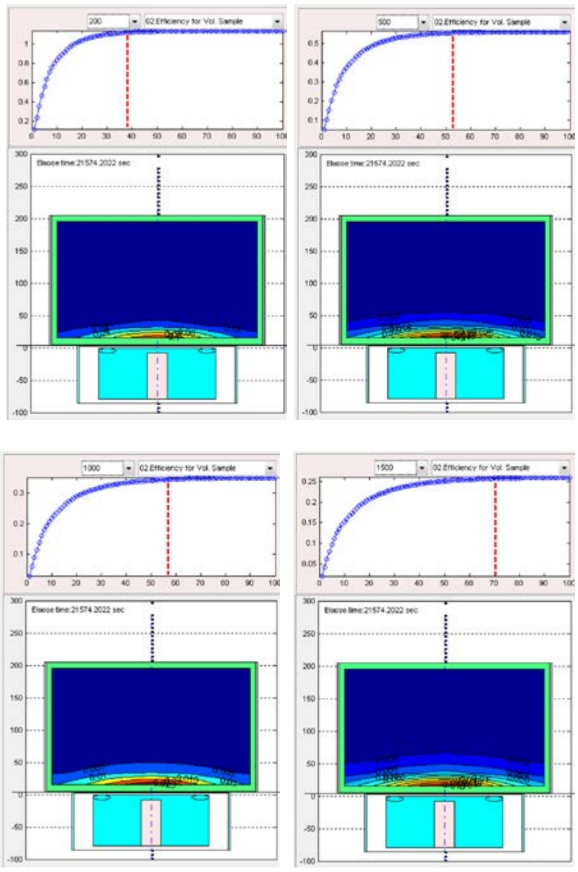

Fig. 2. The distribution of detection efficiency and V_{MED}. The left side of the upper row corresponds to 200 keV and the right side corresponds to 500 keV. The bottom line corresponds to 1000 keV and 1500 keV respectively from left to right.

The calculation results of V_{MED} according to energy are summarized in Table 1. The total volume of the source is 567,504 cm^3. In the case of 1500 keV, the volume of actual contribution to the detection efficiency is only 14,070 cm^3. This result is about 2.5% of the total volume.

Table I: Calculation result of V_{MED} by EXVol

Energy[keV]	200	500	1,000	1,500
V_{MED}[cm^3]	3,525	6,720	10,380	14,070

3. Conclusions and Further Works

As a result of the study, γ-ray detection efficiency and radiation distribution were obtained in the large volume and high density medium source. And we found the $V_{MED.}$ This result shows the necessity of calculation of V_{MED} and the need to reflect on the actual measurement situation. The detection efficiency distribution obtained through above process will be used as an input data for the future development of coincidence summing correction technique.

Acknowledgements

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